



# **Evaluation of Auditory Characteristics of Communications and Hearing Protection Systems (C&HPSs) Part I – Sound Attenuation to Low-Intensity Sounds**

**by Paula Henry and Rachel Weatherless**

**ARL-TR-5050**

**January 2010**

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## **Evaluation of Auditory Characteristics of Communications and Hearing Protection Systems (C&HPSs) Part I – Sound Attenuation to Low-Intensity Sounds**

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**Human Research and Engineering Directorate, ARL**

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14. ABSTRACT  Devices that provide hearing protection, situational awareness, and radio communications are often referred to as Communications and Hearing Protection Systems (C&HPSS). Soldiers use these systems while deployed to navigate within their environment, communicate with their team members, and protect their hearing. Each of the three features of select C&HPSS (hearing protection, speech communication, and situational awareness) was evaluated by the U.S. Army Research Laboratory in order to obtain data that is independent from that provided by the manufacturer. This report is the first in a series of three reports and focuses on the sound attenuation obtained from three commercially available C&HPSS: Sennheiser SLC-110, Nacre QuietPro, and Silynx QuietOps. Real-ear attenuation at threshold values were obtained for 12 listeners with each of the three systems. The results showed that the Nacre QuietPro provided the greatest amount of attenuation for low-intensity sounds followed by the Silynx QuietOps. The Sennheiser SLC-110 provided the least amount of attenuation and the greatest variability across participants. The general pattern of attenuation provided across stimulus frequencies was similar for all three devices.					
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## 1. Introduction

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Dismounted Soldiers need to hear what is happening within their immediate surroundings (have situational awareness), communicate with other Soldiers over radios, and be protected from hazardous continuous and impulse noise (hearing protection). These three hearing abilities are essential for dismounted Soldiers and can be seen as conflicting goals for development of such multipurpose communication devices. Balance must be maintained between hearing protection and auditory situational awareness, which is often the biggest challenge for a developer. Hearing protection devices that cover or plug the ears (like earmuffs or earplugs) will provide hearing protection and good radio communication, but they are likely to reduce the situational awareness for the individual Soldier. Leaving the ears open allows for good situational awareness but not protection against hazardous noise. Providing all three aspects within a single device can be very challenging.

There are several devices available which provide hearing protection yet still allow for adequate situational awareness and radio communications. These devices are often referred to as Communications and Hearing Protection Systems (C&HPSs). The U.S. Army needs information on how these systems function in a militarily-relevant environment in order to determine devices which should be provided to Soldiers as well as determine appropriate areas for research to improve the effectiveness of these devices.

In the evaluation of C&HPS, the three auditory aspects need to be evaluated: attenuation provided for hearing protection, speech intelligibility of radio communication, and auditory localization as a measure of situational awareness. Sound attenuation can be provided to the user through passive or active means. Passive attenuation is provided by the mere presence of the device without any processing of the sound. Active attenuation cancels or reduces the background noise by introducing a signal which is opposite in phase and time to cancel out the first sound (Kuo and Morgan, 1999; Oppenheim et al., 1994). Active noise processes are referred to as active noise cancellation (ANC) or active noise reduction (ANR). A popular implementation of ANR is in the headphones marketed to frequent fliers for listening to music on airplanes. ANR reduces low-frequency noise better than high-frequency noise.

The goal of this part of the three-part study was to measure the passive sound attenuation provided by three in-the-ear C&HPSs using Method A (experimenter fit) of the Real-Ear Attenuation at Threshold (REAT) procedure (ANSI, 2002). The values obtained are intended to demonstrate best-case scenario attenuation from the products but will be overestimates of real-world performance of these devices (Berger, 1986; Franks et al., 2000; Royster et al., 1996). The attenuation measured by each of the C&HPS will be used to determine which devices will be used in the other two portions of the study.

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## 2. Methods

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### 2.1 Procedures

Sound attenuation of the passive aspect of the C&HPSs was measured using the REAT procedure outlined in ANSI S12.6-1997 (R2002) with Method A (experimenter fit). The REAT procedure measures the subjective attenuation provided by hearing protectors for low intensity stimuli by measuring thresholds to narrow band stimuli in unoccluded (open ear) versus occluded (plugged) conditions and calculating the difference in values. REAT is a subjective measure of attenuation.

All measures were conducted within Building 520 at Aberdeen Proving Ground, MD. Instrumentation included the three C&HPSs, a plumb bob to maintain the participant's position in the center of the room, three Bose 802 Series II loudspeakers and accompanying amplifiers, a calibrated GSI\* Arrow† audiometer, two Hafler P3000 amplifiers and a response button. The participant was seated in the center of a reverberant chamber. The loudspeakers were arranged in the room to create a diffuse stimulus presentation.

Pulsed one-third octave narrow bands of noise were presented over the loudspeakers through the audiometer at the seven octave frequencies of 125–8000 Hz. Participants pressed a response button to indicate when the sound was heard. Investigators manually recorded the participant's perceptual threshold of hearing and entered the values into a spreadsheet for data analysis. Thresholds were obtained to the nearest 5-dB increment via an adaptive 10-down, 5-up methodology (ANSI, 2002).

Unoccluded (open ear) and occluded (three C&HPSs with the power turned off and battery removed) pairs were tested with the ordering of systems and occluded/unoccluded conditions counterbalanced across listeners. Batteries were removed from the devices to ensure that no noise generated by the device or active noise reduction was operational during the test. Each pair of unoccluded ear and C&HPS trials was repeated in accordance with the ANSI standard (ANSI, 2002). The measurement of each pair of thresholds took ~20 min for a total of 60 min for measurements to be obtained from the three C&HPSs.

### 2.2 Participants

Twelve civilian volunteers between the ages of 21 and 46 ( $M = 34$ ) participated in the study. Nine of the volunteers were female and three were male. None of the participants had extensive prior experience using the C&HPSs. All participants had normal sensitivity defined as pure-tone hearing thresholds of  $\leq 25$  dB hearing level (HL) at audiometric frequencies from 125 to 8000 Hz

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\* Grason-Stadler Instruments is a subsidiary of Viasys Healthcare Inc., Madison, WI.

† GSI Arrow is a trademark of Viasys Healthcare, Inc., San Diego, CA.

(ANSI, 2004). All data were collected in compliance with regulations from the Institutional Review Board at the U.S. Army Research Laboratory. Informed consent was obtained from each participant prior to their participation in the research study.

## **2.3 Communications and Hearing Protection Systems (C&HPS)**

A review of commercially available C&HPSs yielded several prospective test devices. In order to be considered for use within the present study, the device had to fit in the ear, provide situational awareness, be able to connect to radios for radio communication, provide some means of hearing protection and be designed for the dismounted Soldier. The C&HPSs that were selected for use in the study were the Sennheiser SLC-110, Nacre QuietPro, and Silynx QuietOps. A brief description of each system follows.

### **2.3.1 Sennheiser – SLC-110**

The Sennheiser SLC-110 is an in-the-ear ultra-lightweight (<1 oz) headset designed to meet the communication and hearing protection needs of infantry Soldiers. A picture of the device is shown in figure 1. The Sennheiser SLC-110 is a product from Sennheiser Government Systems Corporation which is a division of Sennheiser Electronic Corporation (SEC) headquartered in Old Lyme, CT. SEC is the wholly-owned US subsidiary of Germany-based Sennheiser Electronic GmbH & Co, KG. The SLC-110 purportedly provides clear, distortion-free hearing and speaking in high ambient noise conditions. Hearing protection is provided by a variety of earplugs and earplug sizes that can be selected by the user. These include single- or triple-flanged plugs and contoured tips. Situational awareness is enhanced by opening an acoustic port on the in-the-ear device that bypasses the attenuation of the earplug. With the port open, the user is protected from impulse and gun-blast noise through a non-linear filter that passes low-intensity sound. According to the manufacturer, up to 30 dB of attenuation can be obtained for impulse noise. No information was provided for attenuation of low-intensity sounds. Information for the system can be obtained from: <http://www.sennheiserusa.com/sgs/>.



Figure 1. Photo of the Sennheiser SLC-110 system in a manikin ear (from [www.sennheiserusa.com/sgs/pdfs/SLC\\_100\\_specification.pdf](http://www.sennheiserusa.com/sgs/pdfs/SLC_100_specification.pdf)).

### 2.3.2 Nacre AS – QuietPro

The Nacre QuietPro is an in-the-ear digital hearing protector and communication headset designed for use with military tactical radios and intercom systems. A picture of the device is shown in figure 2. Nacre AS is a company based in Norway. The QuietPro system uses a digital signal processor to facilitate automatic, adaptive digital hearing protection through active noise reduction in addition to its passive attenuation. According to the manufacturer, the QuietPro helps protect the user's hearing by attenuating ambient noises and canceling excessive acoustic peaks and impulses, resulting from nearby running engines, explosions, and gun shots. Using both passive and active means, Nacre states that QuietPro can achieve 34–42 dB attenuation, but there is no specification regarding the attenuation provided to low intensity sounds versus that provided to impulse noise. The device is fit in the ear with disposable Comply<sup>\*</sup> canal tips that were specifically designed for use with the QuietPro system. The Comply tips are available in three sizes: small, medium, and large. Information for the system can be obtained from: <http://www.nacre.no>.



Figure 2. Photo of the Nacre QuietPro system (from [armorcorpus.com/products.html](http://armorcorpus.com/products.html)).

### 2.3.3 Silynx Communications, Inc. – QuietOps

The Silynx QuietOps is an in-the-ear tactical communication headset designed for use by dismounted Soldiers. A picture of the device is shown in figure 3. Silynx is a Delaware Corporation whose principal location is in Rockville, MD. The QuietOps allows users to monitor one or two communications devices simultaneously: two radios or a radio and an intercom. The device allows the user to determine which communication channel has priority over the other or the user can program the device to have each communication device going to a different ear. The QuietOps is fit to the listener's ear with a compressible foam plug that sits on to the end of the device. The foam plugs are disposable and come in three sizes: small, medium, and large. No information is provided from the company regarding attenuation. Information for the system can be obtained from: <http://www.silynxcom.com/>.

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<sup>\*</sup> Comply is a trademark of Hearing Components, Oakdale, MN.



Figure 3. Photo of the Silynx QuietOps system (from <http://www.janes.com/events/exhibitions/dsei2007/sections/daily/day1/allinone-tactical-headset.shtml>).

### 3. Results

REAT was calculated as the difference between the unoccluded and occluded thresholds with the pairs of values averaged for each C&HPS. REAT was calculated for each of the seven one-third-octave frequency bands as outlined in ANSI S12.6-2002. Table 1 shows the average REAT values and corresponding standard deviations obtained for the three C&HPSs across the seven frequency bands in the study.

Table 1. Average REAT values and standard deviations for the 12 participants for the three communications and hearing protection systems.

C&HPS	Frequency (Hz)						
	125	250	500	1000	2000	4000	8000
Silynx QuietOps	17.5 ± 8.6	17.3 ± 8.4	15.4 ± 9	17.1 ± 9.4	23.8 ± 7.6	27.3 ± 9.8	34.1 ± 13
Nacre QuietPro	23.3 ± 8.4	24.6 ± 9.4	25.4 ± 10.7	26.3 ± 8.5	29.2 ± 6.1	31.9 ± 5.2	37.1 ± 6.5
Sennheiser SLC-110	3.7 ± 2.7	3.3 ± 3.9	5.2 ± 6.3	8.5 ± 9.6	15 ± 10.5	10.8 ± 5.8	17.5 ± 11.2

As seen in the table, the C&HPSs differed in the amount of attenuation they provided. The Nacre QuietPro provided the most attenuation (23–37 dB) followed by the Silynx QuietOps (15–34 dB). The Sennheiser SLC-110 provided the least amount of attenuation (3–17 dB). For some of the participants, the attenuation provided by the Sennheiser SLC-110 was 0 dB resulting in no isolation from the background noise. All three systems provided gently sloping attenuation across the frequencies tested with more attenuation provided for the high frequencies and less attenuation for the low frequencies.

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## 4. Discussion

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REAT values were measured from three in-the-ear C&HPSs. These devices were selected based on the criteria requiring a commercially available device that fits in the ear canal, providing situational awareness, providing a means of radio cation, and providing some degree of hearing protection. The REAT method is a measure of the change in threshold values with and without the devices in place. This method establishes the attenuation provided for low intensity sounds, though no measurements were made of the devices in response to high-level or impulse noises.

Of the three devices tested, the Nacre QuietPro device provided the most attenuation followed by the Silynx QuietOps. The Sennheiser SLC-110 provides the least amount of attenuation to the user (including no attenuation at some frequencies for some participants). In addition, variability in the REAT values was greatest for the Sennheiser SLC-110. The general pattern of attenuation provided across stimulus frequencies was similar for all three devices. In general, variability increased as audiometric frequency increased across all three devices.

Method A (experimenter fit) (ANSI, 2002) was used in fitting each of the C&HPS systems. This is known to provide the best-case scenario or most attenuation when testing REAT on hearing protection devices (Berger, 1986; Franks et al., 2000; Royster et al., 1996). Previous investigators have demonstrated that attenuation values measured in the laboratory setting are often much higher than what is obtained in real-world environments.

The differences seen in attenuation values between the three devices are most likely due to the seal obtained with the different devices. Clearly, the two devices that used compressible foam tips resulted in the best seal and therefore the best attenuation. The Sennheiser SLC-110 uses a soft plastic tip, but the tip did not conform well to the individual users' ears.

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## 5. Conclusions

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Three commercially available C&HPSs were evaluated on their level of laboratory tested attenuation provided to the wearer based on experimenter fit. The measurement of REAT documents the passive attenuation provided by the devices in response to low-intensity noise. The amount of attenuation provided for low-intensity noise varied across devices with the Nacre QuietPro providing the highest amount of attenuation followed by the Silynx QuietOps. The Sennheiser SLC-110 provided the least amount of attenuation of the three devices. The differences in attenuation values measured from the three devices are due to the seal of each device's ear tip to the ear.

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